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SUGGESTIONS FOR THE MANAGEMENT OF SPRUCE STANDS IN THE NORTHEAST

By MARINUS WESTVELD, *Silviculturist, Northeastern Forest Experiment Station,*[1] *Branch of Research, Forest Service*

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INTRODUCTION

Red spruce (*Picea rubra*) because of its abundance and wide distribution throughout New England and New York State has long been recognized as one of the most important timber trees of the Northeast. It first attained value during the early colonial period as ship-building material, but not until the growing scarcity of northern white pine (*Pinus strobus*) created a demand for a substitute did red spruce become an important factor in the general lumber trade. It was the paper industry, however, which was ultimately to place the heaviest demands upon this species. The discovery that red spruce was eminently suited for the manufacture of paper pulp brought into demand also the two less important spruces native to this region—black spruce (*P. mariana*) and white spruce (*P. glauca*). Balsam fir (*Abies balsamea*) and eastern hemlock (*Tsuga canadensis*) species, commonly growing in mixture with the spruces, also find their way into pulpwood mills to supplement the waning supplies of red spruce.

For several decades red spruce has formed the chief source of supply for the paper industry. Forty-three per cent of the pulpwood now used is spruce, an additional 21 per cent is balsam fir and eastern hemlock, and the remainder consists of various species of pines and hardwoods. The Northeast now contributes nearly two-thirds of the domestic spruce and fir pulpwood consumed. The total cut of spruce and fir in this region alone is well over two million cords yearly, a million and a half of which is pulpwood.

The pulp and paper industry should be independent of foreign sources for its raw materials. Actually, however, to meet the in-

[1] Maintained in cooperation with the Massachusetts Agricultural College.

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creasing demands of the industry, heavy importations of pulpwood are made each year from Canada, and large quantities of wood pulp yearly find their way into American ports from the north-European countries. How to perpetuate the valuable pulpwood species and increase the timber growth on pulpwood lands are problems of vital concern. Studies indicate that under the favorable growing conditions existing in the Northeast the productivity of pulpwood lands can be greatly increased, even possibly to the point of growing sufficient spruce and fir to supply the entire needs of the region. Any effort in this direction will, however, necessitate intelligent forest management based on certain results of recent investigations.

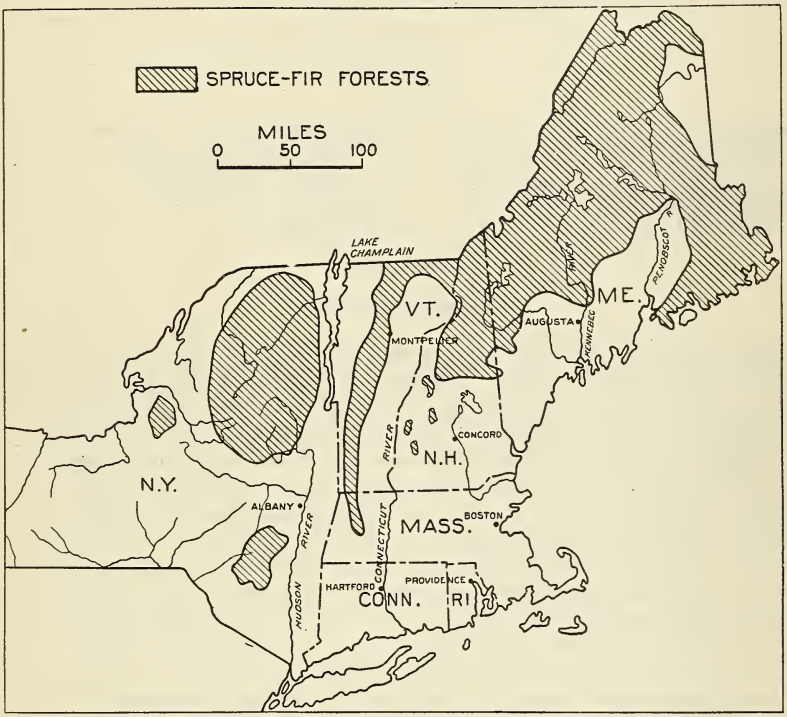

FIGURE 1.—Forest regions in northeastern United States

THE SPRUCE-FIR FORESTS

The spruce-fir forests of the Northeast cover an extensive area in what is known as the spruce and northern hardwoods region. This region extends from the Berkshires in western Massachusetts northward through the Green Mountains of Vermont, westward across the Adirondack Plateau in New York, and eastward through northern Vermont and New Hampshire and all of Maine, except the southwestern part of the State. (Fig. 1.) The five principal spruce types found in this region are spruce flat, spruce hardwoods, spruce slope, spruce swamp, and old-field spruce. The stands themselves vary greatly in composition, ranging from the pure spruce and fir stands commonly encountered in the spruce-slope (fig. 2) and old-field spruce types, to the considerable admixture of hardwoods fre-

quently observed in the spruce-flat and spruce-hardwoods types. (Fig. 3.)

SPRUCE-FLAT TYPE

The spruce-flat type is characteristic of the better-drained sites above the swamp areas and extends to the lower slopes, occupying the flats and low ridges and knolls above lakes and streams. Here the soil is moist and shallow and contains many bowlders; the forest floor is often covered with Hypnum mosses, and a thin mat of hard-

FIGURE 2.—A virgin stand of spruce in spruce-slope type. Note the abundance of young spruce and fir growing beneath the mature stand

wood leaves is frequently found on the knolls and ridges. The principal species found in this type are red spruce and balsam fir, generally mixed with such hardwoods as red maple (*Acer rubrum*), paper birch (*Betula papyrifera*), and yellow birch (*B. lutea*), with occasional white spruce, northern white pine, eastern hemlock, and northern white cedar (*Thuja occidentalis*) scattered throughout. The upper margin of this type is marked by the appearance of beech (*Fagus grandifolia*) and sugar maple (*A. saccharum*). The spruce-flat type, occupying large areas in the level regions of Maine, northern New Hampshire, Vermont, and New York, is of consider-

able commercial importance. The timber is of much better quality than that found in the swamp type, and the growth is more rapid.

SPRUCE-HARDWOODS TYPE

This type occupies well-drained sites and prefers deep moist soils. It is most frequently encountered above the spruce-flat zone and below the upper slopes. Red spruce is the chief species found in mixture with balsam fir, yellow birch, beech, red maple, and paper birch. Eastern hemlock is also frequently present. Red spruce

FIGURE 3.—A virgin stand of the spruce-hardwoods type, where spruce and fir commonly grow in mixture with beech, birch, and maple

reacnes its best individual development in this type as do also the hardwoods with which it is associated. This type is of major commercial importance and is extensively represented throughout the spruce region.

For the purpose of discussion two subtypes will be recognized in the spruce-hardwoods type. The first of these, the yellow birch-spruce subtype, usually borders the upper margins of the spruce flats or occurs on gentle slopes or benches within the spruce-hardwoods type. Yellow birch and, to some extent, red maple and

paper birch are the important hardwoods found here in mixture with red spruce and balsam fir. The yellow birch-spruce subtype shows many characteristics of the spruce-flat type and is practically equivalent to what in Maine is termed the yellow birch type.

A second subtype, the sugar maple spruce, occurs on lower slopes and ridges, and may be regarded as a transition between the spruce-hardwoods type of the spruce forests and the northern hardwoods type. Sugar maple, beech, and yellow birch are the principal hardwoods and make up a considerable proportion of the stand. Red spruce, though generally well developed and of good quality, occurs much less frequently here than in the spruce-hardwoods type proper. These stands are usually associated with well-drained and fairly deep soils, though quantities of large rocks are often present. The type forms a considerable proportion of the Adirondack region, and is also well represented in Vermont, New Hampshire, and Maine.

SPRUCE-SLOPE TYPE

The spruce-slope type occupies the upper slopes, which are usually steep, rocky, and covered with but a thin layer of soil. While spruce predominates in this type, balsam fir, yellow birch, and paper birch are usually associated with it. The timber customarily grows in thick stands producing high yields, but grades off into trees of poor quality and stunted growth at the upper limits of the type. The spruce-slope type is an important one in the mountainous sections of New York and New England.

SPRUCE-SWAMP TYPE

This type, of minor importance, occupies the poorly drained areas near lakes and streams, occurring most abundantly in Maine and New York. The soil is usually peaty in character, impervious, and often supports a ground cover of sphagnum moss of considerable depth. The most characteristic tree is the black spruce, with balsam fir, tamarack (*Larix laricina*), northern white cedar, eastern hemlock, and northern white pine often present. Black ash (*Fraxinus nigra*), red maple, paper birch, and yellow birch are frequently represented. This type is of minor importance, and growth is slow except on the upper marginal zone. Windfall is common, on account of the boggy character of the soil and the consequent shallow rooting of the trees.

OLD-FIELD SPRUCE TYPE

The old-field spruce type occurs scatteringly throughout the region, but principally in northern New England. It is restricted to old pastures and abandoned agricultural lands which produce excellent growth and high yields. Pure stands of red spruce are common in this type; although balsam fir, white spruce, and occasionally tamarack and northern white pine appear in mixture. The pure red spruce stands are particularly characteristic of Vermont, the mixed stands occurring more frequently in Maine and New Hampshire, where white spruce often supplants red spruce to the extent of forming pure or nearly pure stands.

EFFECT OF PAST AND PRESENT TREATMENT OF SPRUCE STANDS

The original forests of the region covered extensive areas in unbroken masses, varying from more or less even-aged stands such as are now met with on old burns and blow-downs to the more common all-aged stands.

During the early logging period only timbers of large size and lumber of high quality were marketable; consequently only trees of the larger sizes were removed. This rough selection system of cutting entailed a minimum disturbance of natural forest conditions. Unconsciously, the lumbermen were practicing a type of silviculture which, in the main, was well adapted to the needs of the stand. The openings made in the forest were quickly restocked with young growth, and thus the forest was maintained in a productive condition.

As spruce stumpage values increased from year to year, lumbermen gradually increased the severity of their cuttings, the development of the pulp and paper industry greatly stimulating this tendency. For the past 15 or 20 years, pulpwood operators have been clean-cutting pulpwood lands, leaving only occasional spruce and fir trees over 5 inches in diameter. Areas which supported nearly pure stands of spruce and fir have been left almost devoid of trees. Where many hardwoods were present, these generally were left to dominate the residual stand and to produce yearly vast quantities of seeds.

RECOMMENDATIONS FOR HANDLING SPRUCE STANDS

GENERAL CONSIDERATIONS

Pulpwood operators naturally desire to devote as large a percentage of their holdings as possible to the production of softwoods, in order to reduce the acreage necessary to insure a continuous supply of pulpwood. Few are perhaps ready to-day to undertake the intensive forestry measures necessary to bring their forest acreages to a minimum; but, even so, much can be done to improve the present spruce stands. The poor state of many cut-over lands is due to the failure to take advantage of such factors as nature has already placed at man's disposal, a failure due largely to ignorance of how these factors operate under different stand conditions.

With the extremely varied conditions encountered in spruce stands, it is well to recognize that proposed silvicultural practices are never uniformly applicable to the region as a whole. Furthermore, practices that are certainly desirable in themselves may not in all instances be applicable at present, owing to economic conditions. Silvicultural operations must take into consideration not only forest type, reproduction requirements, and condition of the stand with respect to its composition, together with density, ground cover, and soil characteristics, but also the existing market conditions. It appears desirable before entering into a discussion of the management of spruce stands, to sum up the more fundamental considerations in the development of such silvicultural practice.

Of first importance is a general abundance of spruce and fir reproduction. Where this is absent or scanty at the time of cutting, subsequent restocking with conifers progresses at an extremely slow

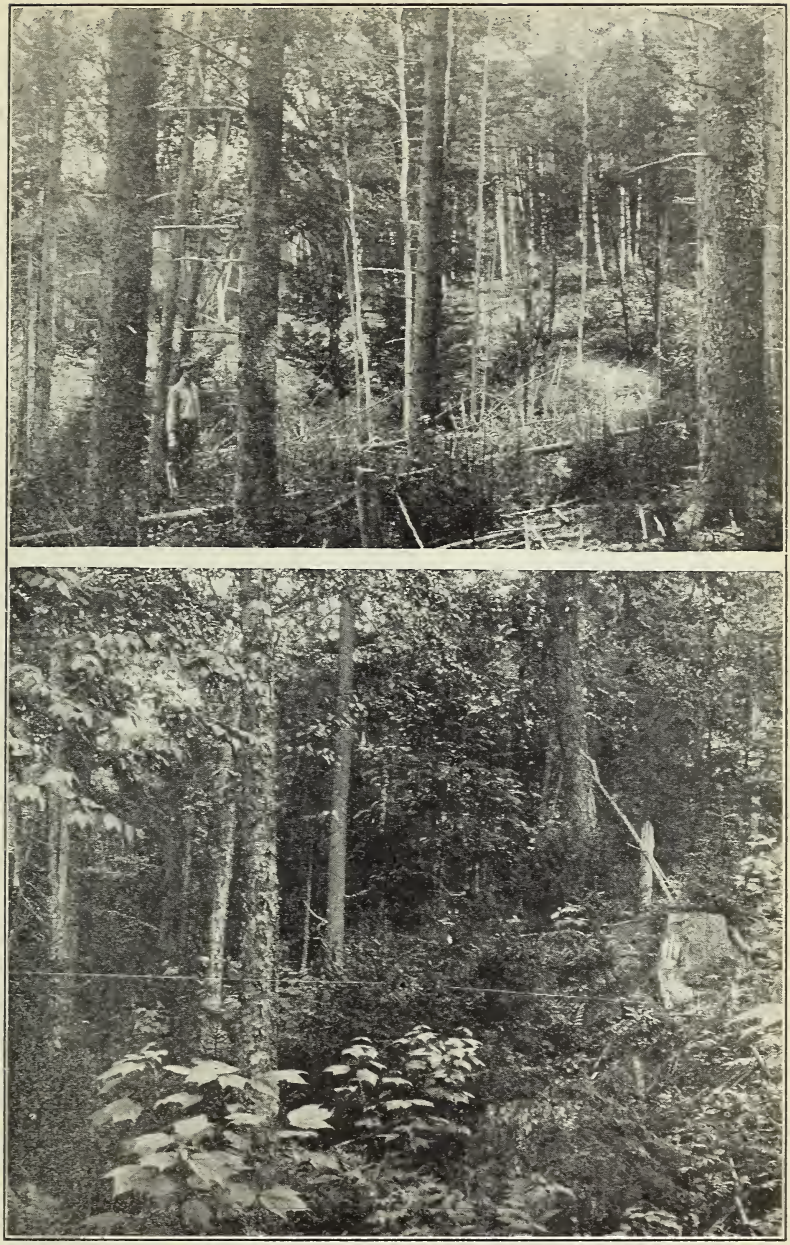

FIGURE 4.—Advance reproduction of spruce and fir. This advance growth forms the main reliance for the next crop of pulpwood, whether unhindered by competitive growth (A) or compelled to force its way through and above young hardwoods and brush (B)

pace or fails completely. The areas supporting abundant reproduction are, in nearly all instances, those on which advance growth was present in the original stand, supplemented to some extent by seedlings germinating from seed crops borne the year prior to cutting. On a large percentage of spruce lands seed trees are not a vital need in the production of a new crop of pulpwood, for advance spruce and fir reproduction forms the main reliance for the new pulpwood crop. Successful management lies mainly in preserving and developing the young advance growth already established in the forest at the time of cutting. (Fig. 4.)

An outstanding characteristic of spruce stands is their remarkable recuperative ability. Even under harsh treatment they reproduce themselves successfully, although the incoming stand is often of inferior quality and composition. Large hardwoods by their heavy

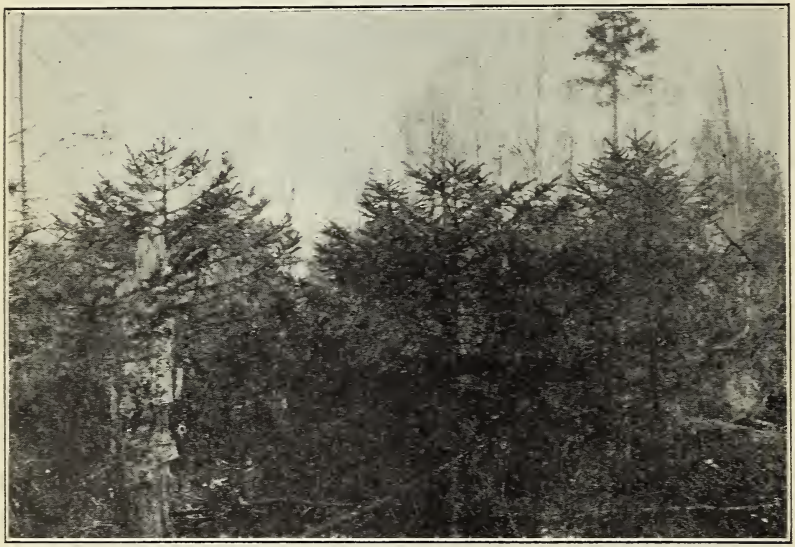

FIGURE 5.—Reproduction left uninjured by logging. This is a valuable asset on cut-over lands. Large size classes of conifer reproduction, especially trees from 2 to 5 feet in height, respond vigorously to logging and maintain their lead over invading brush and young hardwoods. Damage to this material should be kept to a minimum

shade and by the interference of their crowns, and young hardwoods by their plentiful numbers and quick growth, frequently prevent spruce and fir reproduction from attaining dominance in the stand. Studies have shown that reproduction below 2 feet in height often fails to compete successfully with incoming underbrush and rapidly growing young hardwoods. Careless damage of young pulpwood growth, particularly on sites favorable to the development of hardwoods, may be chiefly responsible for the conversion of former mixed spruce-hardwood stands into pure hardwoods. Operators holding their lands for the production of successive crops of pulpwood should recognize the future crop values in young pulpwood growing stock and modify their logging practice to protect and preserve this growth. (Fig. 5.) In the spruce region as a whole, the problem next in importance to that of forest protection is that of getting the

desired composition and bringing it successfully through the competitive stage to the point where its position in the ultimate stand is assured.

The danger from wind throw and wind breakage should be constantly borne in mind. Although red spruce and balsam fir are tolerant species, naturally adapted to a selective system of cutting, a strong tendency to wind throw prevails because of their shallow root system and the thin soils in which they grow. High winds will often overthrow all trees on extensive areas. Where spruce and

FIGURE 6.—Wind-broken red spruce. Spruce, however, is more liable to wind throw than wind breakage. Balsam fir is particularly subject to wind breakage, due to the common occurrence of heart rot, which greatly weakens the tree

fir grow in mixture with hardwoods, they receive the support and protection from their deeper-rooted associates, which greatly reduces this danger. Fir, being subject to weakness from heart rot, is particularly susceptible to wind breakage. Even in uncut stands, numerous balsam firs are broken at a point 5 to 12 feet above the ground because of heart rot. Spruce only occasionally suffers from wind breakage under stress of heavy winds. (Fig. 6.)

By following the few simple, practical measures involved in effective fire protection and conservative logging practice, much can

be done toward maintaining spruce lands in a fairly productive state. These measures should, however, be considered as merely preliminary steps to the adoption of intensive forestry practice. Intensive measures are especially necessary to restore spruce lands which, through neglect, have greatly deteriorated in composition and are therefore falling far short of producing full timber crops.

As a prerequisite to the practice of intensive forestry, and previous to actual cutting, a classification of all lands should be made, based on the composition of the stand, the character of the soil, and the kind, size, and density of reproduction. All these factors strongly influence the choice of the method of cutting to be employed. Of these, the density and height of reproduction are particularly significant. With such information in hand, the progressive order in which areas are to be cut can be determined and should be adhered to in so far as market and logging conditions will permit. Cutting should be so graduated as to permit seedlings to come in and reach 2 to 5 feet in height before the protective cover of the main timber stand is removed. Aside from intensive cultural treatment, nothing is so effective in the management of spruce stands as regulation of the time of cutting.

Certain sites lend themselves more readily to the management of spruce and fir than do others. Even the application of intensive forestry measures may fail to maintain pulpwood species at reasonable cost on certain sites in the spruce region that are distinctly favorable to hardwood production. If conversion to softwoods can not be accomplished at reasonable cost the endeavor should be to perpetuate and develop the young hardwoods already established. Timberland owners in the Northeast should not be alarmed at the encroachment of hardwoods in portions of the spruce-hardwoods type. Who can predict what demands there will be 15 or 20 years hence for high-quality hardwoods? They may be as eagerly sought after as high-grade pine and spruce are to-day. Hardwoods are prolific seeders, reproduce themselves without difficulty or expense, and on the whole are rapid growers. It is entirely consistent with good forest management to devote to the production of high-grade hardwoods such areas in the spruce region as show strong hardwood-producing tendencies. It must be recognized that hardwoods in mixture with spruce will be a factor that most operators must deal with for an indefinite period. Successful management of these stands depends on the development of markets for hardwood species.

The slow development of any but water transportation, while hindering in no way the marketing of softwoods, has been one of the chief factors in keeping hardwoods in this region off the market. Because of their tendency to sink, hardwoods can not be successfully driven on streams for any great distance. With the softwoods in many instances already removed, there is small inducement for the lumberman to parallel his waterways with a costly railroad transportation system, in order to log relatively light residual hardwood stands of comparatively low value. On the other hand, in certain instances where a logging-railroad system was developed primarily for the exploitation of softwood timber, increasing stumpage values are already making it possible to log hardwoods in conjunction with the

softwoods at a profit. This practice has been successfully carried out by one large pulp company in New Hampshire. This company has induced a hardwood operator to establish a plant adjacent to its pulp mills. The company contracts to deliver to this plant a specified quantity of hardwood logs annually. All species of hardwoods common to the region are utilized, largely for furniture and wooden-heel stock.

Integration of hardwood-using plants with pulp mills will do much toward making the practice of forestry on pulpwood lands an economic possibility. In this connection the fact should not be overlooked that hardwoods may in the near future form an important source of supply for pulpwood. The forest products laboratory, at Madison, Wis., is at present endeavoring to perfect a comparatively inexpensive process for reducing northern hardwoods to paper pulp, and has already met with some success in this project.

CUTTING METHODS

In formulating cutting methods it is essential to draw sharper lines of distinction than those afforded by type differentiation. Each condition within the type must be recognized and treated in accordance with its requirements. This is particularly desirable in the spruce-hardwoods type, where there are the widest variations in stand composition, reproduction, and soil conditions. Similar variations also occur in spruce flats, but usually to a less degree. The spruce-swamp and spruce-slope types on the whole are much more uniform. Methods of cutting will be discussed separately for pure softwood stands and mixed hardwood-softwood stands, since they represent two distinct sets of conditions.

PURE SOFTWOOD STANDS

The spruce-swamp and spruce-slope types, and not uncommonly areas in the spruce-flat type, possess certain characteristics in common which make them susceptible to the same forms of silvicultural treatment. Pure to nearly pure stands of spruce and fir in these types are not unusual; conifer reproduction is ordinarily abundant; the thin soil is conducive to wind throw, but at the same time unfavorable to the development of hardwoods; and the cover of deep humus is unfavorable to the establishment of hardwood seedlings. As a general policy such stands should be clear-cut. Cut-over lands of this character, clear-cut of all merchantable material, bear uniformly good stands of young softwood growth. With abundant reproduction already established, removal of the old growth makes available the necessary light and nutrients for a sufficiently rapid development of the reproduction to forestall competition from brush and other growth. Seed trees, aside from being unnecessary, occupy good growing space and are usually doomed to destruction through wind throw. Groups of thrifty young timber, even though merchantable, may well be reserved for future growth.

Where young even-aged stands of spruce and fir approaching pulpwood size are poorly stocked with reproduction, removal of the entire stand would open the way for the invasion of vigorous forms of competitive growth, which, once in possession of the cut-over area, would preclude restocking of pulpwood species for a long

period. Under these conditions a shelter-wood cutting appears advisable. Under this system, from one-fourth to one-half of the trees are removed in such a way as to open up the stand uniformly, the number cut depending on the type of soil and size of the trees. This greatly reduces root competition and at the same time permits an influx of sunlight, creating favorable conditions for the establishment of spruce and fir seedlings. Thinning similar to shelter-wood cuttings made by the Forest Service some 20 years ago in stands of this character in Corbin Park, N. H., at elevations of 1,400 to 1,500 feet, worked out very successfully. Wind throw following cutting was very slight, and reproduction came in abundantly; yet enough shade was cast to discourage the development of heavy raspberry and other undesirable weed growth. Owing to danger from wind throw, great care should be exercised in shelter-wood cutting. After a period of 5 or 10 years, during which seedlings have become well established, the remainder of the stand with its increased growth may be logged, leaving the young stand of reproduction to develop normally.

MIXED HARDWOOD-SOFTWOOD STANDS

Where the spruce-hardwoods type constitutes a considerable portion of the operator's holdings, the question of how to make these lands produce their quota of pulpwood is an extremely important and perplexing one. The common practice of limiting cutting to the softwoods in a mixed stand is beneficial only to the extent that the openings thus created permit partial release of advance growth. It may even prove a disadvantage, because of the encroaching canopy of hardwoods, unless followed by special silvicultural treatment such as girdling. Where advance reproduction of the desirable species is adequate, best results are obtained by cutting all merchantable hardwoods and softwoods, the rather scanty canopy of the residual stand of decadent and overmature trees having little adverse effect on the advance growth. Where birches are prevalent, the crown canopy is likely to be further reduced by the attacks of the bronze birch borers, or other adverse agencies, when once a stand has been opened up.

Through the application of this system it is possible in mixed stands of the spruce-flat type and yellow birch subtype to maintain spruce and fir at least to the extent of their original representation. The degree to which this advance growth is benefited is determined by the severity of the cutting. There is much to indicate that the persistent removal of hardwoods in mixed stands will eventually so change the soil cover as to improve seeding conditions for spruce and fir, and thus gradually produce a pure-conifer type.

In putting these cutting methods into effect, height of reproduction must always be taken into account. (Fig. 7.) The mere presence of advance spruce reproduction is in itself no assurance that it will ultimately form a portion of the next timber crop. It is essential that the reproduction being released be of sufficient height to compete successfully with invading hardwoods and other competing growth. In spruce flats and in the yellow birch-spruce subtype, where soil and drainage favor less the development of hardwoods, height is less important. Nevertheless, it is desirable even on these soils that softwood reproduction have an average height

of 2 feet, and in the sugar maple-spruce subtype it should be approximately 4 feet tall before cutting operations are started, in order to prevent the slow-growing conifers from being choked out. On areas supporting undersized seedlings, a preparatory cutting or girdling of a few of the larger hardwoods will result in an acceleration in height growth of the released seedlings and will hasten the time when a final cutting of the old stand can be made.

In mixed stands of hardwoods and softwoods inadequately stocked with advance spruce and fir reproduction, any system of cutting, at present practical, will result in increasing the proportion of hardwoods. However, the method of removing hardwoods in advance of softwoods may have a limited application. It presupposes a market for hardwoods, involves added logging costs, and would be limited probably to deep soils and sheltered locations, where danger of wind throw is reduced. However, this method, if practicable,

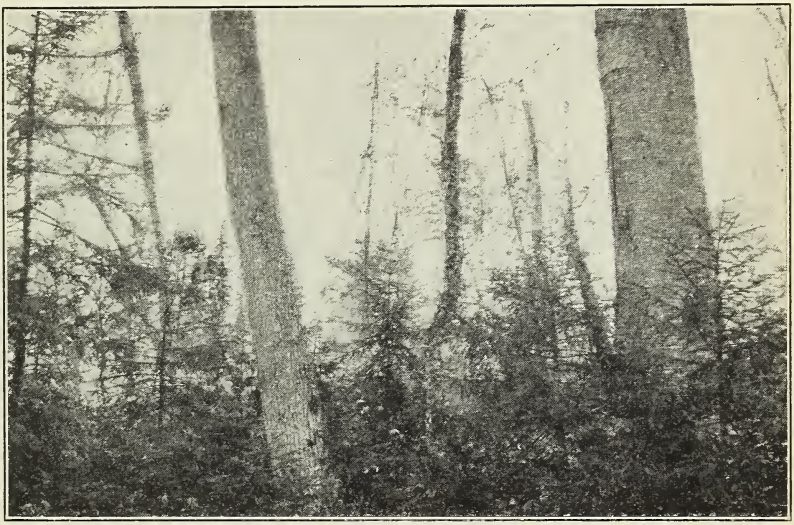

FIGURE 7.—Abundant spruce and fir reproduction is often found growing beneath the canopy of mature stands even where hardwoods predominate. When softwood reproduction has attained a height of from 2 to 5 feet the old timber may be cut without much danger of young invading hardwoods crowding out the conifer reproductions

accomplishes one important thing—through a reduction in the source of hardwood seed, the usual crops of spruce and fir seed have a much better chance for germination and establishment in the openings. After the softwood growth is well established, the residual stand of spruce and fir may be logged, and at that time hardwoods that have come in since the first cutting and are interfering with the development of the young stand of spruce and fir can easily be cleaned out.

In mixed stands unsatisfactorily stocked with spruce and fir reproduction such as is characteristic of the sugar maple-spruce subtype, continued pulpwood production can be accomplished only through clear-cutting and planting, followed later by cleanings—expensive operations that seem justifiable only under special conditions. It is very questionable under present economic conditions whether any special attempt involving an outlay of money should be

made to maintain spruce and fir in this subtype. Such stands should be managed with the primary purpose of improving and perpetuating the young growth already established, the production of softwoods being a secondary consideration.

Clear-cutting of these stands, in which mature and overmature trees predominate, permits the rapid development of straight, clean-boled young trees—largely hardwoods. Such sapling spruce and fir as may be present in the stand will also be given distinct aid in recovery and growth. If the stand is, however, genuinely all-aged it can best be cut under the selection system, by which the older age classes are removed and the younger classes held for increased increment and quality growth. How heavy a selection cutting should be made in all-aged stands depends to a large extent on the prevalence of birch in mixture. Because of the likelihood of damage to newly exposed birch crowns, such as is generally attributed to the bronze birch borer, it appears advisable to cut more lightly in all-aged stands containing a prevalence of birch and to remove birch trees which, because of their position, would otherwise be exposed to the sun.

PROTECTION OF YOUNG GROWTH

Damage to young growth during logging ranges from 20 to as high as 40 per cent of the young stand. Part of this loss is inevitable, but needless and avoidable losses should be eliminated. At present young spruce and fir trees are drawn upon heavily for the construction of bridges, skidways, and corduroy roads for which other species could be substituted. Much of the damage to young growth in swamping out skid roads is unnecessary; seldom is any attempt made to circle trails around clumps of reproduction to avoid destruction. Losses in advance growth caused by logging can be reduced only through close supervision and inspection. An inspector could be profitably employed solely to keep these losses at a minimum.

CONTROL OF STAND COMPOSITION

Since advance reproduction is normally the basis of the future stand the relative representation of spruce and fir in that stand is already largely determined; and it is questionable whether any scheme of cutting will have any material effect on the relative abundance of spruce and fir in the next crop of pulpwood. Any system of cutting involves the opening up of the stand, and to this influence fir invariably responds more quickly than spruce. Fir is aggressive; spruce, persistent. Almost any measure adopted to aid the development of spruce appears equally or more favorable to the development of fir. Under present systems of cutting, it is inevitable that fir should have an increased representation in the succeeding stand. Frequent and heavy cutting of fir in mixed stands of spruce and fir should ultimately tend to increase the representation of spruce. As a measure for keeping spruce stands in a healthy and growing condition there is much to be said in favor of such frequent cuttings.

GIRDLING

A simple and inexpensive method of destroying the dense overhead canopy of residual hardwoods in mixed stands is to girdle and

kill the hardwoods, thus releasing the understory of conifers and giving it the opportunity to increase in growth. (Fig. 8.) Studies show that over a period of several years height growth of seedlings on girdled areas is from three to four times as rapid as on ungirdled areas. Girdling as a means of increasing the percentage of conifers is particularly successful in the spruce-flat type and the yellow birch-spruce subtype, where the released reproduction meets with less competition from invading young hardwoods than in the sugar maple-spruce subtype, where girdling must often be later followed by weeding to assure the conifers of a dominant position in the new stand.

Discretion must of course be exercised at all times in applying this measure. Operations can well be delayed for a few years following

FIGURE 8.—Rapid growth of spruce and fir reproduction following removal of a large yellow birch tree. The larger size classes of reproduction, 2 to 5 feet in height, grow rapidly following logging and succeed in maintaining their ascendancy over encroaching brushy growth. Cutting or girdling hardwoods for releasing this class of reproduction is a distinct aid in maintaining or increasing the representation of conifers

logging, to enable the operator to determine more definitely which trees constitute a menace to advance growth. No money should be spent in girdling trees which are not suppressing advance reproduction, or whose crowns show evidence of deterioration. Girdling should be restricted to areas where the prospect of hardwoods acquiring a market value is remote; otherwise, selective girdling should be practiced, eliminating only trees of poor form and quality.

Earlier returns, of course, can be realized in stands where the trees to be released are merchantable or near merchantable size than where they are only of sapling size, since 40 to 60 years must elapse before small reproduction can be harvested.

Several methods of girdling are employed in the northeast. The most common and satisfactory method, known as hacking, consists of delivering slanting blows with a sharp ax, severing the bark com-

pletely around the trees. Notching and peeling are also used, but are more expensive. Girdling operations can be undertaken most effectively and cheaply during the winter season, costs varying from $1 to $2 per acre, depending on the number and size of hardwoods to be girdled.

Death from girdling usually takes one to three years. This gradual process is a distinct advantage over the sudden removal of hardwood crowns through cutting. The gradual breaking down process of the limbs and trunks of girdled trees also results in far less fire risk and damage to young growth than are occasioned by slash from cutting.

That girdling of hardwoods to release young spruce and fir for increased growth can be a profitable undertaking is conclusively demonstrated in a girdling experiment of the Forest Service in 1905 in a hardwood stand containing a dense understory of spruce and fir at Corbin Park, N. H. The experiment consisted of three plots—one heavily girdled, the second moderately girdled, and the third left as a control. Measurements at the end of a 22-year period indicated that volume growth on the heavily girdled plot was more than five times as rapid as on the ungirdled plot, and on the moderately girdled plot more than three times. From a financial standpoint, too, both the moderate and heavy girdling proved to be a profitable undertaking.

WEEDINGS

Weeding or cleaning, in which the young hardwoods are cut back by machetes or hand axes, may be advisable in stands where spruce and fir reproduction is not well enough established to assure it a position in the stand and an advantage over the invasion of sprout and seedling hardwoods that is likely to follow cutting or girdling. The exact age at which to make a weeding, its intensity, and the question of whether any weeding whatsoever is required, depend to a great degree on the keenness of the struggle between the competing species. For example, where there is no advance reproduction and undesirable hardwoods spring up simultaneously with conifers, the hardwoods soon outstrip the pulpwood species, and may completely crowd them out of the stand, unless an early weeding is resorted to. (Fig. 9.) Where advance reproduction of softwoods is already present, weeding may not be necessary for a period of years; and under favorable conditions the height advantage of the pulpwood species may be sufficient to obviate weeding entirely.

On spruce-slope sites, which are not particularly favorable to hardwoods, spruce will often attain dominance without the assistance of weeding operations. On the stronger hardwood lands such as occur in the spruce-hardwoods type, where thrifty merchantable and unmerchantable hardwoods tend to dominate the stand at an early age and ultimately to crowd out considerable numbers of the conifers, the value of the better hardwoods, such as ash, sugar maple, and paper and yellow birch, should be recognized, and weeding operations should aim to release these species as well as spruce and fir. Beech and red maple, as well as the dwarf maples, are more effective in arresting the height growth of the more valuable species than are the intolerant pin (fire) cherry (*Prunus pennsylvania*) and aspen (*Populus tremuloides*), and, therefore, require earlier weeding.

Under average conditions most effective weeding can be accomplished five to eight years after girdling and cutting, especially in the spruce-hardwoods type where soil conditions favor rapid growth of numerous young hardwoods. Even where soil conditions are more favorable to softwood production, and competition between desirable and undesirable species in the stand is less keen, weeding between five and eight years after cutting may be only slightly less desirable. Delay in weeding in such areas will result in deterioration in composition, increased weeding costs, and diminished returns.

Next to be considered are cut-over areas between 8 and 15 years of age, which have passed the period when weeding can be done by hand

FIGURE 9.—Twelve-year-old cutting in spruce and hardwoods type invaded by dense growth of pin (fire) cherry. Young hardwoods compete strenuously with spruce and fir for a position in the new stand

or with a knife at minimum cost, and where the ax must be used at somewhat greater cost.

Last to be considered for weeding are cuttings over 15 years of age, where the undesirable species form a complete overstory to the desirable elements of the stand. Such areas often result from a partial stocking of advance reproduction of desirable species at the time of cutting. The more rapid-growing hardwoods and weed species take quick possession; subsequent restocking and development of conifers progresses very slowly and over a long period. Weeding on such areas would undoubtedly benefit the suppressed stand of reproduction, but the cost per acre is abnormally high. An equal sum of money spent on young cut-over areas such as have been described above would place many more acres in a productive growing condition.

Weeding experiments in the spruce region are not old enough to permit definite figures on results. Some idea of the possibilities may be gained, however, from a comparison of stands of different composition in the White Mountain area of New Hampshire. Yields on lands naturally free from competing hardwoods show from two to three times the volume recorded for areas where hardwood competition is keen.

Naturally, weeding costs vary greatly, depending on the size and number of stems to be weeded, the intensity of the weeding, and the number of weedings required. On experimental plots in 9-year-old cuttings in the White Mountains, $4 per acre was spent in weeding one plot and $2 in weeding another. The heavier weeding on the first plot removed 5,000 young hardwood stems per acre, and released approximately 1,800 young spruce, whereas the lighter weeding on the second plot removed 2,400 young hardwoods and released 1,100 young conifers. In the $2 as well as the $4 weeding a sufficient number of conifers were released to provide full stocking. At this stage of the experiment it is impossible to say whether or not a second weeding will be required to give permanent dominance to the conifers.

Although weeding or cleaning operations involve actual outlays of money with no immediate returns in sight, pulpwood operators holding their cut-over lands for future growth should give them serious consideration, for very real benefits do accrue in the form of greatly increased yield and value of the pulpwood species thus released. Cleanings will undoubtedly play an important part in the future management of spruce stands, since they represent one certain method of regulating and determining the quality and yield of the next pulpwood crop.

GRAZING

Since nearly all grazing animals browse on hardwood reproduction and shrubs in preference to conifers, grazing is of material assistance in keeping down the undesirable sprout and brush growth which tends to monopolize freshly cut-over areas at the expense of spruce and fir. It is quite evident that many of the pure stands of spruce and fir that have come up in old pastures owe their freedom from hardwoods to the continued browsing of young hardwoods by cattle, sheep, or hogs during the early development of the stand. (Fig. 10.) Grazing as a cheap and effective means of freeing young conifers from undue competition can at least be carried out on a small scale with satisfactory results.

SLASH DISPOSAL

Although in the handling of spruce cut-over lands, disposal of slash constitutes one of the major problems, not only of stand regeneration, but also of fire control, it has thus far been practiced on private lands in the spruce region only to a limited degree. Fortunately, good markets for pulpwood make possible the utilization of tree tops down to 3 to 4 inches in diameter, and thus greatly reduce the amount of inflammable material in the woods; but even so it is not unusual to find over 25 per cent of the ground area covered with slash, and considerably more where hardwoods are cut in conjunction with conifers. (Fig. 11.) In view of the fact that

FIGURE 10.—Twelve-year-old cutting in the spruce-hardwoods type in which hardwoods competition has been controlled by proper grazing by livestock. Spruce and fir now permanently dominate the stand

FIGURE 11.—Slash in windrows on 1-year-old cutting area logged for spruce, fir, and hardwoods. Depth of slash about 4 feet. Many years must elapse before such areas are again available for reproduction

heavy accumulations of softwood slash not only crush and kill advance reproduction, but prevent the establishment of new reproduction for 15 to 20 years, it becomes doubly important to work out a more effective slash disposal. Softwood slash constitutes both a fire menace and a hindrance to the establishment of reproduction for nearly three times as long a period as hardwood slash, and its reduction is, therefore, essential.

In most of the Northeastern States the disposal of slash along the public roads is required by law. This requirement might well be extended by private owners to other especially dangerous places. A system of partial disposal, in which all dense masses of softwood slash are burned as well as lesser accumulations along roads and trails, would serve to fireproof cut-over lands fairly adequately and would afford some relief from smothering. The cost of such operations, when handled by a well-trained crew, should not exceed 30 or 40 cents per thousand board feet.

Owners who already perceive the advantage of intensive efforts to encourage the growing of maximum crops of pulpwood on their lands will be willing to go beyond these partial measures to release the young growth and protect its development. Disposal of slash through piling and burning will serve this purpose very satisfactorily, for not only is additional space thereby made available for timber growth, but danger from fire is decreased and the possibilities of fire running through cut-over areas and destroying valuable advance growth are greatly reduced. Piles of moderate size compactly built by a trained brush-disposal crew and burned during late fall or early spring usually result in a clean burn and do little damage to advance growth, provided the piles are so located that they are not in direct contact with advance growth. Care should also be exercised to select a time when weather conditions insure safe burning.

A variation of piling and burning often referred to as "progressive burning" consists in burning the slash as logging proceeds. This method has been used successfully in the White Mountain National Forest. A fire is started and fed with slash from the trees felled near by, new fires being started as the cutting moves on. Fire damage to the forest floor and young growth is held to the relatively small area actually burned over. This method also reduces logging costs, since removal of slash from the area prior to skidding results in lower skidding costs. Its use, however, is limited to periods of snow cover or when continued rains make burning safe. Slash accumulated during other periods of the year should be piled and burned later when weather conditions permit.

Lopping of conifer slash without scattering is not recommended, since neither the fire hazard nor the danger of smothering seedlings is greatly reduced thereby. Lopping and scattering alleviate the situation in some degree, reducing slash density and hastening decay through contact with the soil. However, the additional expense involved in scattering might better be spent in piling and burning, which would eliminate the high fire danger the first season following logging and permit a more rapid restocking. Although light slash does not constitute a serious handicap to reproduction, truly adequate fire protection demands that both light and dense slash should be

burned. One fire sweeping over logged-off land can destroy all advance growth and defer restocking for a long time. (Fig. 12.)

The cost of fireproofing cut-over lands through the complete disposal of softwood slash by burning will probably never fall below 75 cents a thousand board feet, and average costs will range from $1 to $1.50. To many this may seem a final argument against such disposal, but the indications are that such intensive protection and encouragement of future pulpwood crops will in the long run pay for themselves.

Burning hardwood slash is out of the question, because of its high cost, and decomposition progresses so rapidly that no special measures for disposal are at present advocated. Lopping as a means of disposal is practiced here and there, but is ineffective in hastening decay and promoting the growth of reproduction and does not re-

FIGURE 12.—Area burned over following logging. One fire sweeping over cut-over lands defers production for a long time

duce the fire hazard sufficiently to justify the cost involved. In fact, lopping is undesirable silviculturally in that it increases the density of the slash and thus distinctly hinders the development of advance reproduction and creates conditions unfavorable for the establishment of new reproduction. Unlopped hardwood tops, on the other hand, because of their open character permit a certain number of seedlings to push their way through successfully.

Closer woods utilization is the most satisfactory means of hardwood slash disposal. For example, in certain sections of the White Mountains limbs and branches to 3 inches in diameter are utilized for cordwood, leaving comparatively little slash in the woods.

SUMMARY

For adequate handling of spruce stands in the Northeast, it is necessary to recognize five main types of spruce-fir forest—the spruce

flat, spruce hardwoods, spruce slope, spruce swamp, and old-field spruce. On these types the clean-cutting operations of late years have seldom been governed by consideration of the importance of advance reproduction, of the splendid recuperative power of these stands when they are rightly handled, or of such obstacles to future productiveness as wind throw and fire. To reclaim these lands and maintain the greatly needed local supply of pulpwood, forest lands must be classified as to their productiveness, the decision must be made as to whether spruce can be encouraged to predominance, or whether utilization can be broadened to include sufficient hardwoods to make the lands profitable in the future.

Cutting methods advocated must be adapted to the individual stand, as must also the measures for protection of young growth, control of stand composition, and slash disposal. No attempt can here be made to specify hard and fast measures to meet the great variety of conditions obtaining locally.

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